

MACHINE DRAWING

L. A. WIRICK.

MACHINE DRAWING

FOR USE OF STUDENTS IN
INDUSTRIAL AND CONTINUATION
SCHOOLS

BY L. A. WIRICK

¶ The lessons outlined in the following pages are elementary in character, being intended for beginners in the subject. They are more particularly applicable to the making of working drawings as used in the manufacture of machinery, and are to some extent introductory to machine design. The principles of mechanical drawing, however, apply to all branches of the subject.

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THE PLAN of this book comprises, first, instruction in the theories upon which working drawings are based; second, directions as to the manner in which these theories are to be applied in the making of working drawings; third, exercises illustrating their application. The book should be carefully studied as a text book and be kept at hand for reference. The exercises are numbered and printed on separate pages, (Job sheets) following the sections explaining them. Each job should be worked out when its number is reached, indicated by 5-a etc., before passing to the next paragraph. In the exercises of Part I the instruments needed for each exercise are mentioned, and no others should be used. The exercises given form a minimum amount of work in connection with the various topics.

CORRECTIONS.

Page 9, Sec. 6, at end add 6-c

Page 23, 12-c should read 13-c.

Page 28, after 17-c, read 17-d instead of 17-b.

Page 36, 21-a should read 21-d.

MACHINE DRAWING

PART I. - - - - THE MAKING OF LINES

Mechanical drawing is so called because instruments are used in making the drawings. The principal uses of such drawings are in connection with the manufacture of machinery and in the practice of architecture and civil engineering. The general principles of drawing are the same in all branches. The details of the operation depend upon the purposes for which the drawings are made. 1

A working drawing is for the use of the persons making the thing represented and should comprise all the information needed by them, so that the finished object will be exactly what was intended by the designer. To accomplish this the drawing must be accurate, complete and clear. Drawings are usually made on common drawing paper in pencil and then copied in ink by tracing them on transparent paper or cloth. The tracings are then used in making blue prints which are sent to the shops as needed.

Drawing paper is made in a variety of grades, of several colors, either in sheets of standard dimensions or in continuous rolls. For ordinary drafting room purposes buff roll paper 36 inches wide is supplied. This is cut into sheets as needed a usual size being 18 in. by 26 in. The drawing itself is made to occupy an inch or two less than these dimensions. Tracing cloth is also in rolls and is cut to the same size sheets for use. When the tracing is finished it is trimmed to a standard size, say 17 in. by 24 in., which is a convenient size for filing and makes prints of a size suitable for shop use. 2.

The drawing paper and tracing cloth are used on a smooth table or drawing board to which they are fastened with thumb tacks. The left hand end of the table or board must be perfectly straight for the tee square.

The number and character of the instruments depends somewhat upon the character of the work to be done. Nine-tenths of the ordinary work done in a drafting room can be done with a very simple set of instruments. The following may be considered essential.

Tee square,	Compasses,	Bow pencil,
Two triangles,	Dividers,	Bow pen.
Scale,	Ruling pen.	

To these must be added a drawing board and a supply of pencils, erasers, pens, drawing ink, drawing paper, tracing cloth, thumb tacks, and a sand paper block. In addition to the list given, which may be considered a standard outfit, there are a few other instruments of value in particular cases. The following are suggested as being of frequent service.

Extra scales,	Protractor,	Wide ruling pen,
Extra triangles,	Curve,	Erasing shield.

It is advised that greater expenditure should be in the way of better quality, rather than a greater number of instruments.

The manner of using the instruments will be explained in connection with the exercises calling for their use.

3. The purpose of a working drawing is to convey information from the designer of a machine to the persons who make the machine and its parts. Before a thing can be made it is necessary to know its shape and size. A working drawing gives this information by means of lines of various kinds and letters and figures so related to each other as to be under-

stood by the various workmen. A working drawing is not a picture, but differs in many respects from the artist's production. Its sole purpose is to convey information; to present the object as it is, rather than as it may appear to be.

The lines of a drawing are principally 4. straight lines and circles or parts of circles.

In a pencil drawing, certain lines used only for construction purposes are made very light. The regular lines of the drawing should be firm and distinct and may be either full or broken. Ink lines (as used in tracing) should be made of several widths according to their meaning.

The pencil for drawing lines should be rather hard, 5H or 6H, and should be sharpened to a smooth flat end. A piece of fine sand paper or emery cloth glued on a block of wood is needed for keeping the point in good order.

Straight lines are made by use of a straight- 5. edge, such as the edge of the tee square or triangle. Only the upper edge of the tee square or the further edge of the triangle should be used as the ruling edge. Horizontal lines and inclined lines are drawn from left to right. Vertical lines and inclined lines approaching the vertical are drawn upward except when near the right hand end of the drawing board, where a downward stroke is more convenient. The pencil should be held with the flat side of the lead against the straightedge, with the point a little away from the edge so as to show daylight between the edge and the line when drawn. 5-a. 5-b.

Horizontal lines are drawn by using the tee square, the head of which is held against the left hand end of the drawing board. Note that all horizontal lines are parallel. 5-c. 5-d.

Vertical lines are drawn by using a triangle with the tee square. Place one leg of the triangle against the tee square and use the other leg as the ruling edge. Note that all vertical lines are parallel to each other, and that horizontal and vertical lines are perpendicular to each other. **5-e. 5-f.**

Oblique lines are drawn by using one or both triangles with the tee square, or by using a single straight edge. The triangles in common use have angles of 30° and 60° on one and of 45° on the other. When used singly with the tee square, these will give lines inclined in six directions. By placing one triangle against the tee square and the other against the first, it is possible to get lines inclined in four more directions. It is more convenient to use the triangles in this way than to resort to the use of a protractor when the required angle is a multiple of 15° . **5-g. 5-h.**

A line can be drawn through two points by placing a straight edge to them. The edge should not coincide with the points but should leave equal daylight between them and the edge. A point is usually located by the intersection of two lines or by a light indentation by the point of the dividers. **5-k.**

A line can be drawn parallel to a given line as follows. Place a triangle so that one side coincides with the given line and place the tee square against one of its other sides. Slide the triangle along the tee square and its edge will always be parallel to the given line. **5-m.**

A line can be drawn perpendicular to a given line as follows. Place a triangle so that its hypotenuse coincides with the given line and place the tee square against one leg of the triangle. Hold the tee square in place and reverse the triangle so that its other leg is against the tee square. The hypotenuse is now

perpendicular to the given line and can be moved along the tee square to any desired position. 5-n. 5-p.

Circles are drawn with compasses fitted with pencil or ruling pen. For small circles a bow pencil or bow pen is used, for large ones a beam compass. The center of a circle is indicated by the intersection of two center lines, usually horizontal and vertical. Center lines are light lines made up of alternate long and short dashes. They do not represent an actual part of the object shown in the drawing but are construction lines used for convenience in constructing the drawing and in making the object itself. After adjusting the compasses to the required dimension (radius) it is manipulated by its handle with one hand. It should be swung around clockwise, with its top slightly inclined forward. 6-a. 6-b.

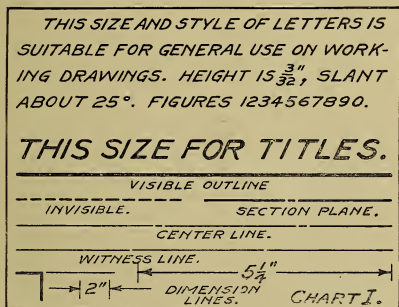
Tangent lines are of frequent occurrence in machine drawing, either a straight line and a circle meeting, or two arcs making a compound curve. A circle and a tangent to it coincide at one point and a radius at this point is perpendicular to the tangent. Two circles or arcs tangent to each other coincide at one point and this point is on a straight line passing through the two centers. The point where two tangent lines meet or coincide has a definite location, but if the lines are properly drawn the point cannot be determined by inspection. Its location can be accurately determined by a simple construction based on the geometrical facts just stated. This rule works both ways and is useful for drawing a tangent arc from a given point on a straight line or circle and for drawing a straight line tangent to a circle at a given point. 7-a. 7-b. 7-c. 7-d.

8. Dividers are used for dividing a line into a given number of parts, or for setting off a line equal to a given line or dimension. The dividers should not be used for taking dimensions from the scale when the scale can as well be applied directly to the drawing. It is proper to use the dividers for this purpose when the same dimension is to be used in several places or repeated along a line. Do not set the points of the dividers or of any other instrument on the scale itself, but on the paper or board along the edge of the scale. 8-a. 8-b.

9. An important purpose of a working drawing is to show the size of the piece to be made. The lines of a drawing represent corresponding lines of the object, and when the lines of the drawing are proportional in length to the lines of the object the drawing is to scale. Working drawings should always be made to scale. If the lines of the drawing are of the same actual length as the corresponding lines of the object, the drawing is full size or full scale. In any drawing made to scale, whether full scale or otherwise, the size of the object can be determined by measuring the lines of the drawing. This is the usual method in some kinds of architectural drawing, but on engineering drawings the sizes are given by figures and dimension lines and the drawing should not be measured. The arrangement of dimension lines and witness or reference lines is shown in Chart I.

The dimensions which should be given on a drawing are those which will be needed by the persons using the drawing, and they should be given in such a way that the pattern maker, lay-out man, machinist or other mechanic can get the dimension he requires directly from the drawing.

The first rule is to work from center lines if there are any; second, give dimensions from finished edges rather than from unfinished ones; third, given dimensions where fits and clearances are required. The location of the dimension lines should be such as to interfere as little as possible with the drawing itself. Figures should read from the bottom and right hand end of the sheet and in the run of the dimension line. For circles give the diameter rather than



The Alphabet of Lines and Letters.

the radius; for an arc give the radius. Do not repeat a dimension on another view. Do not put figures on a line used for any other purpose than as a dimension line.

The scale used for laying off dimensions should be of a character suited to the work being done. Architectural work is all laid out in feet and inches;

hence the architect's scale has the units, representing feet, divided into twelfths, representing inches. Civil engineering work is frequently laid out in feet and tenths; hence the engineer's scale shows decimal divisions. Machine work is almost entirely laid out in inches and binary fractions; hence on the scale best suited to this kind of drawing, the units are divided into halves, quarters and eighths.

In using a scale it should be applied to the drawing and the dimensions marked off as required. 9-a. 9-b. 9-c.

10. Besides the lines of the drawing itself and the construction lines used with them, a drawing contains figures for giving the dimensions and letters for notes sometimes required to make the drawing entirely clear. The most important thing in regard to letters and figures is that they must be distinct. A style and size in common use is shown in Chart I. Lettering is done freehand with a finger stroke, avoiding almost entirely upward or backward movements. Use a round pointed medium pencil (about 4H). Draw guide lines for the top and bottom of each line of words. Care must be used in spacing between lines, between words and between the letters in a word. Uniformity of height and slant will add greatly to the legibility and neatness.

¶ Never use the scale as a straightedge for drawing lines.

¶ Never use the tee square against any side of the drawing board except the left hand end.

¶ Never use a carpenter's or machinist's scale for drafting purposes.

MACHINE DRAWING--Job Sheet No. 1

5-a. (Straightedge.) Draw several straight lines about 3 in. long, in different directions. Do not measure. Make the ends distinct and definite.

5-b. (Straightedge.) Draw two intersecting lines and through the point of intersection draw several more lines. Care must be used that all the lines pass exactly through the one point.

5-c. (Tee square.) Draw several horizontal lines side by side, about 3 in. long and 1-4 in. apart. Do not measure.

5-d. (Tee square.) Refer to 5-a. Select one of these lines and from each end of it draw a horizontal line to the right. Select another line and draw two horizontal lines ending at the given line without crossing it.

5-e. (Tee square and triangle.) Draw several vertical lines side by side, about 3 in. long and 1-4 in. apart. Do not measure.

5-f. (Tee square and triangle.) Refer to 5-c. Draw several vertical lines across these lines but not extending beyond the top and bottom lines.

MACHINE DRAWING--Job Sheet No. 2

5-g. (Tee square and 45° triangle.) Draw horizontal and vertical intersecting lines and through the intersection draw two 45° lines.

5-h. (Tee square and two triangles.) Draw horizontal and vertical intersecting lines and through the intersection draw lines inclined at all 15° intervals. Note that this makes a symmetrical figure, dividing the space around the point into 24 equal angles.

5-k. (Triangle.) Draw three pairs of intersecting lines thus locating three points. Connect the three points with three straight lines, making a triangle.

5-m. (Two triangles.) Refer to 5-a. Draw a line parallel to each of these lines and about 1-4 in. distant.

5-n. (Two triangles.) Refer to 5-b. Determine if any of these lines are perpendicular to each other.

5-p. (Two triangles.) Refer to 5-k. Through each apex of this triangle draw a line perpendicular to the opposite side of the triangle. Note whether these three lines intersect in one point.

MACHINE DRAWING--Job Sheet No. 3

6-a. (Tee square, triangle and compasses.) Draw a circle about 2 in. diameter. Locate the center by means of horizontal and vertical center lines before drawing the circle. On the same center draw another circle a little larger than the first one and another a little smaller.

6-b. (Tee square, triangle bow pencil and compasses.) Set the bow pencil at about 3-4 in. and draw two equal circles tangent to each other and having their centers on the same horizontal center line. Draw another circle that will exactly enclose (circumscribe) the other two. Note the location of the center of the large circle.

6-c. (Tee square, 30-60 triangle, compasses and bow pencil.) Draw 6 circles 1-2 in. diameter equally spaced on a 4 in. circle. There should be horizontal and vertical center lines for the 4 in. circle. The 4 in. circle should be considered a center line for the small circles. The other center line for each small circle should be a short radial line.

MACHINE DRAWING--Job Sheet No. 4

7-a. (Tee square, triangle and compasses.) Draw an arc about 2 in. long with a radius of about 2 in. From each end of the arc draw a tangent line about 2 in. long.

7-b. (Tee square, triangle and compasses.) Draw a straight line about 3 in. long. At each end draw a tangent arc of 90° (exact) with a radius of about 1 1-2 in.

7-c. (Tee square, triangle and compasses.) Draw a circle about 2 in. diameter. Draw two horizontal and two vertical lines touching the circle (tangents). Draw a circle passing through the intersections of the four straight lines.

7-d. (Tee square, 30-60 triangle and compasses.) Draw a vertical line and two lines inclined 60° from it all passing through one point. With this point as a center draw a circle about 2 in. diameter. At each point where the circle intersects a straight line, draw a line tangent to the circle, making a hexagon.

MACHINE DRAWING--Job Sheet No. 5

8-a. (Tee square, dividers and triangle.) Draw two horizontal lines about 2 in. long and 1-2 in. apart, side by side. Draw two vertical lines exactly the same length and the same distance apart, crossing the two horizontal lines so as to make a symmetrical figure. A symmetrical figure should have center lines showing the axes of symmetry.

8-b. (Tee square, triangle, compasses and dividers.) Draw a circle about 3 in. diameter. Divide the circumference into 5 equal parts and draw a radius to each point.

9-a. (Triangle and scale.) Refer to 6-c. Draw a line diagonally across the large circle, measure this diameter and put down the figures on the dimension line.

9-b. (Tee square, triangle and scale.) Refer to 7-d. Draw horizontal witness lines in extension of the top and bottom sides of the hexagon, draw a dimension line between them, measure the distance and put in the dimension.

MACHINE DRAWING--Job Sheet No. 6

9-c. (Tee square, 45° triangle and scale.) Make a drawing as shown in Fig. 5, the dimensions being 3 in. by 4 1-2 in. for the outer rectangle, with 1-2 in. space between it and the inner rectangle. Note that the drawing consists of 4 horizontal lines and 4 vertical lines, spaced so as to give the required size. First



Fig. 5. Job No. 9-c.

lay the scale on the paper along the tee square and mark off 4 points locating the four vertical lines. Shift the scale and mark off 4 points for the horizontal lines. These "points" are light pencil lines about 1-32 in. long.

Draw 4 light (construction) lines with the tee square through the last 4 points about 5 in. long. Draw the 4 (heavy) vertical lines through the first 4 points and terminating at the construction lines. Draw the 4 (heavy) horizontal lines coinciding with the construction lines but ending exactly at the ends of the 4 vertical lines. Draw the 45° lines spaced 3-32 in. apart, beginning at the upper left hand corner. Do not measure this spacing but get it uniform.

MACHINE DRAWING

PART II. - - - THE MEANING OF LINES

The lines of which a drawing is composed 11. are arranged to represent the corresponding lines of the object drawn.

The surfaces of an object may be of any number and are either plane or curved. Where two surfaces meet there is an edge, more or less acute, and this edge is represented by a line of the drawing.

If a curved surface of an object is only partly visible, there is an imaginary line separating the visible from the invisible part. This line is also represented by a line of the drawing.

Hence the lines of a drawing represent two different things: the edges of the different surfaces of the object, and the boundary lines of the visible parts of curved surfaces. Usually no distinction is made between these two meanings.

From any particular point of view, one or 12. more of the surfaces of an object may be seen, but not all of them. Consequently, one view in a drawing is not sufficient to give complete information as to all parts of the object. By looking at it from different directions, enough views may be made to show all parts of the object and thus furnish complete information. The point of view may be in any direction from the object. For working drawings the positions usually taken are directly above or below, in front of, or at either side, giving top, bottom, front and side or end views. These may be considered the six standard views. The view from directly above is a plan and that from any side is an elevation.

Consider a cube. It has six surfaces, or faces. As seen from above or below or from any side, it presents one face only, which is a square figure, and the drawing of each view is composed of four straight lines representing the four edges of the one visible surface.

Consider a cylinder. It has three surfaces, two plane and one curved. A view of either end presents one surface, the drawing of which is a circle representing the edge. As seen from any side, it presents one half of the curved surface. A drawing of any side consists of four straight lines, two of which represent the edges where the curved surface joins the ends, and the other two represent the limits of the visible part of the curved surface.

Consider a sphere. It has but one surface, uniformly curved. As seen from any direction it presents one half of this curved surface. The drawing of any view of a sphere is a circle, representing the boundary line of the visible half of the surface.

These geometrical bodies are typical of the forms occurring in machine parts. Any object may be considered in the same way making a study of the different surfaces and edges. Drawings of the different views will be made up of lines representing the edges if there are any, and the furthest visible points or lines of the curved surfaces. **12-a.**

It is seldom necessary to draw all of the six standard views of an object. In a majority of cases two or three are sufficient. Additional views should be made whenever greater clearness can be obtained by so doing. On the other hand, additional views which give no additional information should not be made. The draftsman must decide from the circumstances of each particular case how many views and what ones will give the best results.

Parts of an object which are not visible from 13. a given point, may, nevertheless, be shown in the view from that point. Such parts are shown by broken lines made up of short dashes. The arrangement of these lines is the same as though the invisible part were seen through the part that hides it from view. Hollow parts, or holes into or through an object are shown in the same way as other invisible parts. 13-a. 13-b. 13-c.

The arrangement of the different views of 14. an object in relation to each other follows definite rules of projection. These rules and principles will be more fully explained in Part V. A working explanation sufficient for practical purposes is given here. Of the six standard views, one may be considered the principal view and the others are arranged with reference to it. The principal view should be the one showing the most detail or the most characteristic features of the object. It is desirable, but not essential, that this view should show the object "right side up" or in its normal position in the completed machine. Let this be considered a front view. A right end view is drawn at the right hand of the front view, a left end view at the left hand. A top view, or plan, is drawn above the front view. A bottom view is drawn below the front view.

The six standard views of an object can be arranged in a model which will clearly demonstrate the required arrangement. Make the six views each on a sheet by itself. Draw a border line one inch outside of the drawing and trim each sheet to this line, making a rectangular card. Arrange the six cards in the form of a box, the drawings on the outside, and fasten them together with strips of gummed paper. Care must be used to have the drawings correspond

in position to the parts of the object they represent. Now cut enough of the gummed strips to allow the six cards to be spread out flat, but remain attached to each other. The drawings thus shown have the correct relation to each other. It is evident that several different arrangements may be obtained by cutting the strips in different places, all of which are correct. 14-a.

15. A section or sectional view is a convenient means of showing the shape of an object at any particular transversal. It is made by assuming that a part of the object is cut away so that a certain invisible part becomes visible. The part of the object remaining beyond the plane of the section, or cutting, is drawn in the regular way, although frequently only the cut surface is shown, the parts beyond being omitted. To show that the view is a section, the part representing the cut surface is hatched by oblique parallel lines which should be light and uniform. A note is also added to show the location of the section, referring to a similar note on some other view. 15-a. 15-b.

16. It is not always possible or desirable to make a drawing full scale. Some pieces are too large to be conveniently drawn in this scale, or so much lacking in detail that a full scale drawing is not as clear as a smaller one. Other pieces are so small that a full scale drawing would be illegible. For these reasons various other scales are used to secure the necessary size and clearness. The usual scales for working drawings, besides full size, are half size, quarter size and eighth size, frequently called 6 in., 3 in. and 1 1/2 in. to the foot, respectively. For small objects, double size scale may be used.

To use any selected scale, consider each unit on the scale to represent an inch, and lay off the required dimensions in the regular way. Do not form the habit of thinking of the dimensions on a reduced scale drawing as the full dimensions divided by two, four, etc., but as the full number of units. The figures to be used in giving the dimensions are such as to indicate the full size of the object regardless of the size of the drawing.

¶ For preliminary practice in using other than full scale, make an arbitrary scale by setting the dividers at random,— about the length of the ruled dash above this paragraph— and set off this dimension a number of times along the edge of a strip of drawing paper. Number these points in order and divide each space into halves, quarters and eighths. Use this scale for making a drawing of a piece such as **12-c**.

¶ To avoid the necessity of dividing the diameter by two for the radius, set the compasses to the given dimension on a scale half the scale being used.

The scheme is also useful for laying off half of a given dimension on each side of a line.

¶ It is sometimes thought to be advantageous to use different styles of cross-section hatching to indicate different materials. Several systems of such conventional hatching lines have been devised, but a complete system is manifestly impossible. In the absence of general agreement and understanding, a key to any system in use is required. The scheme is of questionable value and should not be employed on working drawings unless required by the rules or custom of the place.

Decimal Equivalents.

8 ths	16 ths	32 nds	64 ths	DECIMAL	8 ths	16 ths	32 nds	64 ths	DECIMAL
			1	.015625			33		.515625
		1	-	.03125			17	-	.53125
			3	.046875			35		.546875
	1	-	-	.0625		9	-	-	.5625
			5	.078125			37		.578125
		3	-	.09375			19	-	.59375
			7	.109375			39		.609375
1	-	-	-	.125	5	-	-	-	.625
			9	.140625			41		.640625
		5	-	.15625			21	-	.65625
			11	.171875			43		.671875
	3	-	-	.1875		11	-	-	.6875
			13	.203125			45		.703125
		7	-	.21875			23	-	.71875
			15	.234375			47		.734375
2	-	-	-	.25	6	-	-	-	.75
			17	.265625			49		.765625
		9	-	.28125			25	-	.78125
			19	.293875			51		.796875
	5	-	-	.3125		13	-	-	.8135
			21	.328125			53		.828125
		11	-	.34375			27	-	.84375
			23	.359375			55		.859375
3	-	-	-	.375	7	-	-	-	.875
			25	.390625			57		.890625
		1	-	.40625			29	-	.90625
			27	.421875			59		.921875
	7	-	-	.4375		15	-	-	.9375
			29	.453125			61		.953125
			-	.46875			31		.96875
			31	.484375			63		.984375
4	-	-	-	.5	8	-	-	-	1.000

Arithmetical Constants.

Ratio of Circumference to Diameter, Pi, - 3.1416.

Reciprocal of Pi, - - - .3183.

MACHINE DRAWING--Job Sheet No. 7

12-a. Draw 6 views of a piece of bar steel 1 in. by 1 1-4 in. by 4 1-2 in. long which has been turned to 1 in. diameter for a length of 2 in. from one end.

13-a. Draw a top view of a piece of cast iron 4 in. square in the bottom of which is a round hole 2 in. diameter.

13-b. Draw a top view of a piece of cast iron 4 in. square on the bottom of which is a round boss 2 in. diameter.

13-c Draw two views of a bar 1 3-8 in. square by 4 in. long with a 3-4 in. hole drilled through it lengthwise.

14-a. Refer to 12-a. Select two of these six views which will be sufficient to give complete information and redraw them in proper relation to each other.

15-a. Refer to 13-a. Draw a section of this piece showing a thickness of 2 in., and the round hole 1 1-4 in. deep.

15-b. Draw a top view (face view) and a center-line section of an O-G cast iron washer 2 1-8 in. to 2 7-8 in. diameter by 3-4 in. thick, with a hole 1 1-16 in. diameter.

MACHINE DRAWING

PART III. - - - WORKING DRAWINGS

Drawings may be constructed from a mental 17. conception of the object to be made; from notes describing the object; from a sketch of the object; from a drawing already in existence, or from the object itself. The draftsman must indeed always have a mental conception of the object he is drawing, but this may be derived from any of the sources enumerated. The designer of a machine may put his ideas into a drawing or he may record them in notes and sketches to be worked out by a draftsman. The notes can also be translated into sketches and these in turn accurately redrawn. If the drawing is to represent an object already in existence a sketch is a convenient means of recording the necessary data as obtained by inspection and measurement of the object.

A sketch differs from a drawing in being made free hand, and is not always complete, especially when used only as a memorandum. When it is to be the basis of a working drawing it should be as complete as the drawing itself. This is particularly the case where it is used as an intermediate step in copying a drawing, or drawing an object already made, or in any case where any change of design is not permissible.

The process of constructing the drawing should be systematic. With the mental conception of the object clearly fixed, decide first what views are necessary and determine their arrangement. After these preliminaries, the first step is to draw the main center lines or the lines of the principal mass of the

object. This should be done in all the views to be made and the progress of the drawing should balance in all the views. The details should next be added systematically, putting in all the items of a series at one time, and the opposite sides of a symmetrical part in order. Center lines should be drawn before the lines of which they are the center. Complete all the details. Then draw witness and dimension lines and put in the dimensions. Add finish marks and notes. Finally check all parts to see that the drawing is complete and correct.

A sketch which is only a memorandum of design usually omits the minor details. These must be supplied by the draftsman according to his own judgment. The draftsman is also called upon to draw up minor details to meet certain specifications, and in this he must also follow his judgment or the custom of the place, subject to the approval of the designer of the machine. 17-a. 17-b. 17-c. 17-b. 17-e.

18. A working sketch is materially different from a memorandum sketch. It is in fact a working drawing made free hand, and hence is lacking in the mechanical accuracy of a drawing. Nevertheless, it must be as complete and as correct as a working drawing. There are three important uses for complete technical sketches, the valuable feature in each case being the saving of time effected. A sketch can be made in much less time than a drawing and in these cases is indispensable. One purpose is for recording a design as it is worked out by the designer of a machine or a part, and this may be made with sufficient detail as to afford complete information to a draftsman who subsequently makes up a set of working drawings. Another purpose is to serve as a shop drawing in emergency where the information must be supplied on short

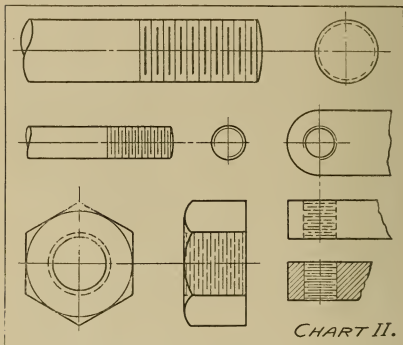
notice, or when facilities for making a drawing are lacking. The third important purpose is as an intermediate step in producing drawings of a machine or detail already made. In making a sketch of an existing object, follow a definite procedure. Study the object and decide what views are necessary, remembering that a free use of notes may save a considerable amount of drawing. On the other hand, it is not necessary to restrict the number of views to the number that will be used in the finished drawing. Start with center lines or with finished (machined) faces, and show the various outlines as they appear to the eye, approximately to scale but without measurement either of the object or the sketch. Carry this through until all parts of the object are shown or described. Next decide what dimensions are to be used and draw in the witness and dimension lines. Finally measure the object (with a two foot rule, not the drafting scale) in as many places as there are dimensions required and enter the figures on the sketch. Calipers and other shop tools may be used for taking the dimensions. 18-a.

A surface that is to be machined is indicated by a conventional mark resembling the letter **f** crossing the line to be finished. Any special finish is denoted by a note such as GRIND. ROUGH TURN. etc. 19.

The way in which a hole is to be made is usually indicated by a note in connection with the dimension as, for example, CORE 2 in. DIAM. TAP 5-8 in. etc.

A conventional drawing of frequent occurrence is that representing the threads of a screw. An accurate drawing is tedious in execution and of no value as a working drawing. There would be one set of curved lines to represent the top of the threads, another set to represent the bottom of the threads, and

a series of diagonal lines for the faces of the threads. All this can be drawn according to the rules of projection, but is of no value in a working drawing. Conventional drawings of screw threads are shown in Chart II. Note that the outline shows the rod or bar before the threads are cut; the top and bottom of the threads are shown by straight lines. Several methods for showing threads are in use, with corresponding methods for tapped holes.



Conventional Screw Threads.

20. There are parts used in the construction of machines which are stock pieces, bought ready made, instead of being made by the factory using them. There are also other parts of frequent and general use which are made in quantities according to standard specifications. It is not necessary to make

drawings of these parts, as they are ordered by number or size or trade name. It is necessary for the draftsman to know the sizes and specifications of these parts in order to make proper provision for their use in connection with the parts for which drawings are made. A large proportion of them are pieces used to fasten other parts together, such as screws, nuts, keys, and pins; also pipe and pipe fittings.

There are two kinds of screw threads in use. The V thread has its sides inclined at an angle of 60° to each other and is perfectly sharp at both top and bottom. The U. S. Standard thread also has its sides at an angle of 60° to each other but has its top cut off to the extent of 1-8 of its pitch and the bottom filled in the same amount.

A draftsman should have tables of various data convenient for reference. The following are among those most frequently used. U. S. Standard screw threads, including number of threads per inch for each diameter of screw, and diameter at root of thread; dimensions of nuts and screw heads; dimensions of machine screws; wire and sheet metal gauges; dimensions of keyways according to the standard of the place; dimensions of taper pins and cotters; dimensions of standard pipe and pipe fittings; drill sizes for various kinds of tapped holes.

Other tables for reference will save time in making calculations. A draftsman will accumulate a stock of such material pertaining especially to the line of work in which he is engaged. Trade catalogs are valuable sources of such information.

REFERENCE TABLES.

U. S. Standard Screw Threads.

a, Diameter of body; **b**, Number of threads per inch;
c, Area at root of thread.

a	b	c	a	b	c	a	b	c	a	b	c
1-4	20	.026	5-8	11	.202	1 1-4	7	.893	2 1-4	4	1-2 3.023
5-16	18	.045	3-4	10	.302	1 3-8	6	1.057	2 1-2	4	3.719
3-8	16	.068	7-8	9	.419	1 1-2	6	1.295	2 3-4	4	4.620
7-16	14	.093	1	8	.551	1 3-4	5	1.746	3	3 1-2	5.428
1-2	13	.126	1 1-8	7	.694	2 4 1-2	2.302	4	3	9.963	

Wrought Iron Pipe.

b, Nominal size; **e**, Internal diameter; **f**, External diameter; **g**, Size of drill for pipe tap.

d	e	f	g	d	e	f	g	d	e	f
1-8	.27	.40	11-32	1	1.05	1.32	1 9-64	3	3.07	3.50
1-4	.36	.54	7-16	1 1-4	1.38	1.66	1 1-2	4	4.03	4.50
3-8	.49	.68	37-64	1 1-2	1.61	1.90	123-32	5	5.05	5.56
1-2	.62	.84	45-64	2	2.07	2.38	2 3-16	6	6.07	6.63
3-4	.82	1.05	29-32	2 1-2	2.47	2.83	2 5-8	7	7.02	7.63

Machine Screws. **h**, Gauge number and number of threads per inch; **i**, Diameter of body.

Taper Pins. **j**, Gauge number; **k**, Diameter of body at large end. Taper 1-4 in. diameter per foot.

h	i	h	i	h	i	j	k	j	k	j	k
2-56	.084	10-24	.189	18-18	.295	0	.156	4	.250	8	.942
4-36	.111	12-24	.216	20-18	.321	1	.172	5	.289	9	.591
6-32	.137	14-20	.242	24-16	.374	2	.193	6	.341	10	.706
8-32	.163	16-20	.268	30-14	.452	3	.219	7	.409		

Weight of Materials. Per cubic inch.

Cast iron,	-	.260	Cast brass,	.284 to .304
Wrought iron,	-	.278	Cast aluminum,	- .093
Steel,	-	.283	Copper wire,	- .321

MACHINE DRAWING--Job Sheet No. 8

17-a. Make a series of drawings from notes and sketches supplied by the instructor.

17-b. Make a complete working drawing of a collar 4 5-8 in. diameter by 1 7-16 in. wide, with the hole 3 49-64 in. diameter. Finish all over.

17-c. Make a complete working drawing of a coupling pin of which the body is 5-8 in. diameter by 3 1-4 in. long, and the head 1 in. diameter by 1-4 in. long. Drill 1-8 in. hole through the body 2 13-16 in. from the head. Chamfer outer corner of the head at 45° to leave 3-16 in. straight.

17-d. Make a complete drawing of a flanged pipe of the following dimensions. Body is 6 1-8 in. outside diameter 5 1-4 in. inside diameter, flanges 10 in. diameter by 1 1-8 in. thick, fillets 3-8 in. radius, length 10 1-4 in. face to face. Finish both faces. Drill both flanges 8 holes 7-8 in. drill on 8 1-2 in. bolt circle.

17-e. Design and draw a bearing bracket to meet the following specifications. Make a preliminary sketch. The pad on which the foot of the bracket rests is 2 1-4 in. by 5 in., machined, the fastening is to be two 1-2 in. cap screws; the bracket is to carry a shaft 1 in. diameter which is parallel to the end of the pad, 1 1-2 in. out from the pad and 3 in. above it.

18-a. Make a series of sketches from a machine to be designated by the instructor. From the sketches make complete working drawings.

MACHINE DRAWING

PART IV. - - TRACINGS AND BLUE PRINTS

It is a general factory practice to furnish **21.** blue prints of the drawings for use in the shops.

Blue prints are made from tracings by a photographic process. The tracings are copies of the drawings made in ink on transparent cloth. The instruments used for this operation are the ruling pen, compasses fitted with pen point, and bow pen, together with the tee square and triangles. For lettering and figures common writing pens are used. They should be of several sizes, rather stiff, and used with a finger stroke only. Black drawing ink is used and a pen-wiper is a necessary adjunct.

The drawing to be traced is tacked to the drawing board after being carefully lined up with the tee square. The sheet of tracing cloth is spread over it, smooth side up, and held in place by thumb tacks. The cloth should be dusted with powdered chalk, soap-stone or fuller's earth to make it take the ink. Rub the powder lightly over the surface with a soft cloth and remove all excess.

The tracing is done by making ink lines on the cloth exactly covering the pencil lines of the drawing beneath. The thickness of the ink lines is gauged by the screw adjustment of the ruling pens. This should be changed as few times as possible, drawing as many lines as convenient with each setting of the instrument. **21-a. 21-b. 21-c.** The work can be done with a saving of time by following a systematic order. Trace first the center lines all over the drawing. These are light lines and it is essential that their in

Intersections are at the exact points on the drawing. Next trace the circles and arcs, making as many as possible with each setting of the compasses. Be sure to set the point of the instrument on the exact intersection of the center lines. Next trace the horizontal full lines, then the vertical and inclined lines. These are heavy lines. This completes the visible outlines. Next trace the broken lines representing the invisible outlines. These are of medium thickness, and the short dashes and spaces should be uniform. Next trace the hatching lines, if the drawing contains any sectional views, and the screw threads. The hatching lines are light lines and should be traced without any attempt to copy the lines as drawn on the paper. Make them uniform in thickness and spacing so as to give the effect of a tint over the section surface. This completes the drawing itself. Next trace the witness and dimension lines. These are light lines. It is not necessary for them to be an exact copy of the drawing, but should be nearly so in the position of the lines and location of the figures. Next add the figures and the notes as given. Finally, check the entire tracing to see that nothing has been omitted. Construction lines used only for making the drawing are not to be traced. 21-a.

22. Certain lines of a drawing represent the edges of the object, or in other words the boundary lines between adjacent surfaces. To add to the clearness and effectiveness of a drawing, it is sometimes desirable to show a difference in the lighting of adjacent surfaces of the object, by the use of shade lines in the drawing. The light is assumed to fall on the object from above, from the front and from the left, each at an angle of 45° . The degree of illumination on any surface depends upon its position and inclina-

tion, and every surface will be in one or the other of two groups, lighted and dark. Upper surfaces, front surfaces and left end surfaces are lighted; right hand and bottom surfaces are dark. To bring out this distinction in a drawing, a line separating two lighted surfaces is made the regular thickness, while a line separating a lighted surface from a dark one is made heavier. The use of shade lines is confined almost entirely to assembly drawings, where it helps to distinguish one piece from another.

It is also of occasional value in detail drawings, to give an effect of relief not otherwise obtainable. In strictness, shade lines belong only to plane surfaces, but in practice, when used, they are applied to plane and curved surfaces indiscriminately, the simple rule being to make all lower and right hand boundary lines heavy. Shade lines are never used on pencil drawings; only on inked-in drawings and tracings

The making of blue prints is not a part of **23.** the draftsman's business, but the process should be understood. As usually practised it is extremely simple. Prepared paper is used and the essential apparatus consists of a printing frame with a glass front and a tray for washing the prints. The operation is as follows. The tracing to be printed is placed in the frame with the inked side next to the glass; on this a sheet of the prepared paper is laid with the sensitized side next to the tracing. The back of the frame is adjusted to hold the paper and tracing in close contact with each other against the glass. The frame is then exposed so that strong light will fall upon the tracing and through it upon the prepared paper.

The ink lines of the tracing prevent the light from reaching the paper beneath them. After a suitable exposure, depending upon the strength of the

light, the transparency of the tracing and the sensitiveness of the prepared paper, the paper is removed from the frame and thoroughly washed in clear water. The result is a copy of the tracing showing white lines on a blue ground. The action of the light is such as to render the chemical preparation on the paper insoluble, while the parts which were covered by the ink lines of the tracing remain soluble and are washed out in the bath. The tracing is in no way affected by the process and may be used repeatedly for making as many prints as may be required.

- ¶ Never use a blotter on inked lines.
- ¶ Never leave the stopper out of the ink bottle.
- ¶ Never leave ink to dry in a ruling pen or compass pen.
- ¶ Never use the ruling pen free hand, that is, without a straight edge or curve to guide it.
- ¶ It is not the tracer's business to revise or in any way "edit" the drawing. The more nearly exact the tracing is to the drawing, the better the job.

MACHINE DRAWING--Job Sheet No. 9

21-a. Make a series of lines with the ruling pen on tracing cloth, using the tee square and triangle so as to become used to the handling of the pen. Set the pen so that it will make a line as wide as the one designated "visible outline" on Chart I. This is a heavy line. A medium line is the width of that designated "invisible" and "section plane." A light line is the width of the one designated "center line." Make several lines of each width.

21-b. Make the same kinds of lines as in 21-a, using the compasses fitted with ruling pen end, and using the bow pen.

21-c. Make a set of lines for reference as an Alphabet of lines. The set should comprise the following:

1. Heavy solid line for visible outlines.
2. Medium, broken line for invisible outlines. (The dashes should be 1-8 in. long with spaces 3-64 in.)
3. Medium, broken line for invisible outlines of small extent. (Dashes 1-16 in. in. long, spaces 1-32 in.)
4. Light, broken line for center lines. (Dashes alternating 2 in. and 1-16 in., spaces all 1-16 in.)
5. Light, broken line for witness and dimension lines. (Dashes 2 in., spaces 1-16 in.)
6. Medium, broken line for location of sections. (Dashes alternating 1 in. and 1-16 in., spaces all 1-16 in.)

21-d. Make tracings of such drawings as the instructor may designate.

MACHINE DRAWING

PART V. - - - - - PROJECTIONS

A point is projected by passing a line 24. through it in any direction. The line is a projection line and any point on it is a projection of the given point. Let m be a projection of the point a and n of the point b ; then a line joining the points m and n is a projection of a line joining the points a and b . In a similar way any line may be projected by projecting points in it, and an entire object by projecting all the lines composing its outlines. It is evident that an infinite number of projections can be made. To be of value they must be used according to some definite system. Several systems of projection have been built up and are in use.

If in a given case all the projection lines are parallel the result is parallel projection. If in any given case the projections all lie in one plane the result is plane projection. If in a given case the projection lines are parallel and the projections all lie in one plane (parallel plane projection), and in addition the plane of projection is perpendicular to the projection lines, the result is orthographic projection. This is the system used in practically all working drawings. Working drawings are made in third angle projection which means that the plane of projection is placed between the object and the point of view. Drawings are sometimes found, made in first angle projection, which results from putting the plane of projection beyond the object from the point of view. Isometric, cabinet and perspective projection are other systems in use for special purposes.

25. The arrangement of views in a working drawing is an application of third angle orthographic projection. The plan or top view is made on a horizontal plane placed above the object, the points of which are projected upward by vertical projection lines. Front, side and end views are obtained on vertical planes by means of horizontal projection lines. The usual views in a working drawing correspond to the three standard planes of projection. These three planes are located at right angles to each other and are then folded or revolved into one plane which represents the plane of the drawing. This revolving of the planes of projection is equivalent to the unfolding of the box model used in Sec. 14 to demonstrate the correct arrangement of views. Of course the views are all drawn, actually, in one plane, but as they would appear if drawn on the respective projection planes.

26. The projection of a line which is parallel to the plane of projection is equal in length to the line itself, but if the line is not parallel to the plane of projection its projection is shorter than the line itself. This is the technical statement of the foreshortening in drawings which is a matter of common observation. In a working drawing it is of no particular consequence, provided the line is shown in its proper length in some other view. If a certain part of an object cannot be shown in any of the regular views and it seems desirable to show the part without foreshortening, it is customary to draw it as it would appear if projected upon an auxiliary plane of projection set up parallel to the given surface and then revolved into the front view plane. Such auxiliary views may be complete, or may show only the detail which could not be clearly shown in the other views. **26-a.**

A drawing does not show surfaces, but only the boundaries or edges of the surfaces. It is evident that where one surface ends another begins, so that an edge belongs to two surfaces, being their intersection. The shape of the two surfaces which meet at an edge, and their relative position will determine the shape of the line which is their intersection. 27.

A point is the beginning of all geometrical matter. A moving point generates or marks out a line; a moving line generates a surface. A line by which a surface is generated may be either straight or curved and the generated surfaces will be of two corresponding classes. Surfaces marked out by a moving straight line are ruled surfaces, and include plane, single-curved and warped surfaces. A plane surface is one in which the generating straight line moves so as to always touch two directing lines which must be straight lines and either parallel or intersecting. A single-curved surface, such as the curved surface of a cylinder or cone, can be made by rolling a plane surface. In such a surface, two adjacent elements, or positions of the generating line, are either parallel or intersecting, and consequently lie in one plane. In a warped surface the generating straight line moves so that adjacent elements are neither parallel nor intersecting. Hence, as two adjacent elements do not lie in a plane, a warped surface cannot be made by rolling or bending a plane surface. An example of a warped surface is the face of a screw thread.

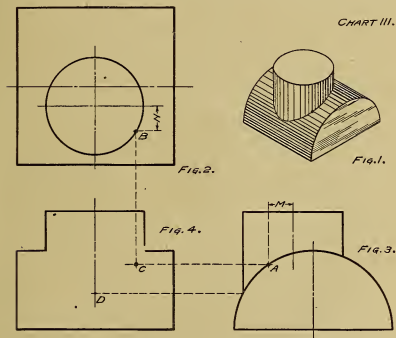
A surface marked out by a curved line moving along a curved path is a double-curved surface. The simplest form is the surface of a sphere. Other examples are the fillets and rounded corners of cylindrical pieces and numerous forms occurring in lathe work.

28. Where two surfaces meet, there is a line belonging equally to both surfaces, and this intersection follows the laws of both surfaces. The intersection of two planes is always a straight line. The intersection of a plane and a cylindrical surface is either a straight line, a circle or an ellipse, depending on the position of the plane relative to the axis of the cylinder. The intersection of a plane and a conical surface is either a straight line, a circle, an ellipse, a parabola or a hyperbola, the so-called conic sections. The intersection of a plane and a spherical surface is always a circle.

The drawing of a line may not show its true shape because the plane of projection may not be parallel to the plane in which the line may lie; and furthermore, some lines do not lie in a plane, as for example, the helix, which is a curve of three dimensions. The true shape of such a line cannot be shown on a plane, but is drawn by projecting it on two or more planes.

The intersection of any two surfaces as seen from any point of view, (or as projected upon any plane of projection,) can be laid out by projecting points in the different views into the required view. Intersections of many kinds are of constant occurrence in machine parts and must be represented in the drawings. A high degree of accuracy is seldom required. The intersection of two cylindrical surfaces is a typical example, and the method of plotting this curve is shown in Chart III. Fig. 1 is a picture drawing representing a cylinder with a vertical axis intersecting a cylindrical surface having a horizontal axis. Fig. 2 is a top view and Fig. 3 an end view of this piece. Fig. 4 is a front view, partially drawn, in which the intersection of the two surfaces is to be shown. It is

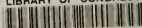
obtained by locating on the top and end views a series of points of the intersecting line, and projecting them to the front view. A round dot in Fig. 1 indicates a point of the intersecting line, the same point being represented by A in the end view. Draw a vertical line through A and with the dividers transfer



Plotting an Intersection.

the dimension M to the top view at N. Draw a horizontal line to the left, cutting the circle at B, which represents in this view the same point as A in the end view. Project A to the left and B downward until they intersect, at C, locating the same point in this view. Repeat this process for as many points as may be needed and then draw a smooth line through them. This is the required line, representing in this view the intersection of the surfaces. 28-a. 28-b. 28-c.

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